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Air Quality Data Analysis System for Interrelating Effects Standards, and Needed Source Reductions: Part 10. Potential Ambient O3 Standards to Limit Soybean Crop Reduction

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16. ABSTRACT

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An Air Quality Data Analysis System for Interrelating Effects, Standards, and Needed Source Reductions: Part 10. Potential Ambient O_3 Standards to Limit Soybean Crop Reduction

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Soybean percent crop reduction was estimated as a function of ambient O_3 concentrations for each of 80 agricultural sites in the National Aerometric Data Bank (NADB) for each available year of data for years 1981–1985. Fourteen O_3 concentration statistics were calculated for each of the resulting 320 site-years of data. The two statistics that correlated best with estimated crop reduction were an effective mean O_3 concentration (1 percent of variance unexplained) and an arithmetic mean O_3 concentration (4 percent unexplained). The worst correlation of the 14 was for the statistic used in the present O_3 National Ambient Air Quality Standard (NAAQS), the second highest daily maximum 1-h O_3 concentration (42 percent unexplained). The number of site-years for estimated percent soybean yield reductions was plotted versus increasing O_3 concentrations for each of the 14 O_3 statistics. A maximum crop reduction line was drawn on each plot. These lines were used to estimate (and list) potential ambient O_3 standards for each of the 14 statistics that would limit soybean crop reduction at agricultural NADB sites to 5, 10, 15, or 20 percent.

The original O_3 National Ambient Air Quality Standard (NAAQS), set in 1971,[1] specified that the second highest daily maximum hourly O_3 concentration (c_{2hih}) measured in a year should not exceed 0.08 ppm. This standard was raised to 0.12 ppm in 1979.[2] The purposes of this paper were to estimate the percentage of soybean crop reduction expected with this 0.12 ppm standard, to determine how well this statistic (c_{2hih}) correlates with estimated crop reduction, to study 13 additional statistics, and to suggest which of these correlate best with crop reduction and might be considered for a new O_3 NAAQS.

Agricultural NADB Sites

The 80 sites called "agricultural" National Aerometric Data Bank (NADB) sites used here were comprised of 68 NADB type 32 sites ("rural-agricultural"), 11 type 41 sites ("strictly remote"), and one type 45 site ("other remote"). These sites were the same ones used in a previous study[3] in which each site was required to have at least one year in 1982–1984 with a valid daily maximum 1-h O_3 concentration available for at least 75 percent of the days in its EPA-specified O_3 season. The O_3 season covers only warm months at northern U.S. sites but all months at southern sites, such as Los Angeles. Although there were three additional NADB sites of type 32 or 45 that met the above requirements, they were not used in this or the previous study since land-use statistics and maps showed populated areas near those three sites. The agricultural sites used here, located in 32 states, are spread across the United States. One purpose of this study was to measure the variability in O_3 concentrations at all of these agricultural sites, even though soybean is not grown near all of them.

The Effective Mean O_3 Concentration at Ambient Sites

Earlier studies[4,5] suggested that crop reduction at an ambient monitoring site can be estimated as a function of the effective mean O_3 concentration, m_e, defined (Equation 2 in Reference 4) as

$$m_e = [(\sum c_h^{-1/v})/n]^{-v} \quad (1)$$

where c_h = each 1-h average daytime (0900–1600, always standard time)[6,7] ambient O_3 concentration measured during a plant's growing season (here defined as June 1–August 31 and called summer)
n = the number of hours of daytime concentration data available during summer
v = a parameter indicating the relative importance of concentration and exposure duration in injuring plants or reducing crop yield

v

A v of −0.354 was calculated for soybean growth suppression (Table IV in Reference 8) from studies of soybean exposed to 0.05 or 0.10 ppm of O_3 for 120, 258, 552, or 798 h. Similarly, v was calculated[4] for soybean leaf injury (−0.378) and pinto bean leaf dry weight reduction (−0.396). The average v for these three effects is −0.376. Future crop reduction studies could be designed to estimate v; presently available crop reduction data cannot be used. However, crop reduction is probably closely analogous to growth suppression, leaf injury, and leaf dry weight reduction, and the average v of −0.376 for these three effects is probably a good approximation of v for crop reduction. This average v of −0.376 was used previously[4,5] to estimate crop reduction and

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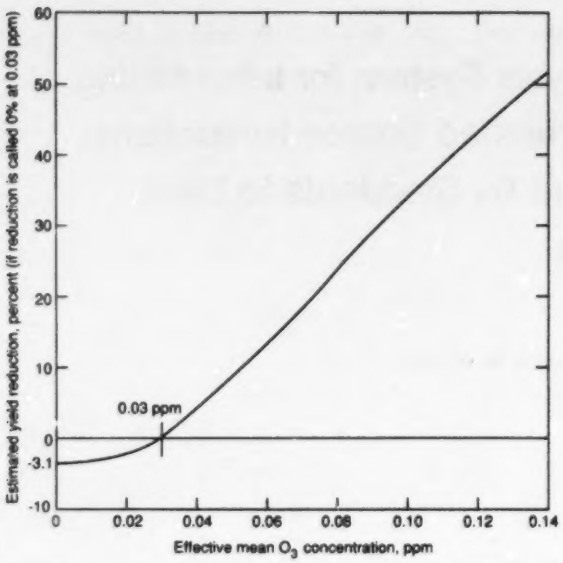

Figure 1. Percent yield reduction estimated (Equation 6) for soybean exposed to various effective mean O_3 concentrations for 75 days (for 7 h/day, totaling 525 h).[4]

was also used here. Using a v of -0.376 in Equation 1, the effective mean was expressed[4] as

$$m_e = [(\sum c_h^{2.66})/n]^{0.376} \quad (2)$$

The arithmetic mean, m_a, was calculated by setting v to -1 in Equation 1:

$$m_a = (\sum c_h)/n \quad (3)$$

If crop reduction were estimated as a function of the arithmetic mean ($v = -1$) instead of the effective mean ($v = -0.376$), the implicit assumption would be that O_3 concentration and exposure duration were equally important in reducing crop yield. Using the concept of an effective mean ($v = -0.376$) suggests that concentration is more important than duration. This v of -0.376 (in fact any v that is greater than -1 and less than zero) stresses the importance of peak O_3 concentrations in affecting plant responses (such as the three responses mentioned above) and suggests that such responses are proportional to concentration raised to the 2.66 power (Equation 2) rather than to concentration raised to the first power (Equation 3). For example, a 1-h exposure to 0.1 ppm of O_3 would be equivalent in cumulative effect to a 6.32-h exposure to 0.05 ppm (Equation 2, since 0.1 is twice 0.05 and $2^{2.66} = 6.32$). (The effect of the exponent of 0.376 in Equation 2 will be balanced by the effect of the exponent of 2.66 in Equation 5.)

If summer daytime ambient O_3 concentrations at a site were highly variable, then Equation 1 suggests that v would be a very important parameter and m_e would be a much better predictor of crop reduction than would m_a. Later analyses here will show, however, that ambient O_3 concentrations at agricultural sites are not highly variable and that crop reduction predicted with m_a does not vary markedly from that predicted with m_e.

Calculating the Effective and Arithmetic Means

The effective (Equation 2) and arithmetic (Equation 3) mean O_3 concentrations were calculated for daytime summer hours (0900–1600) of each available year of data for years 1981–1985 for the 80 sites mentioned above, giving 320 site-years of data.

Estimating Crop Reduction with the Effective Mean O_3 Concentration

In earlier studies of soybean and other plants, percent leaf injury data were fitted to a lognormal mathematical model,[8,9] as were crop reduction data.[4] The resulting parameters for soybean were used here to estimate percent crop reduction (Figure 1) for each site-year of data by entering the effective mean O_3 concentration into the model equation:[4]

$$z = 0.478 \ln(t \cdot m_e^{-1/v}) - 0.42 \quad (4)$$

Using a v of -0.376,

$$z = 0.478 \ln(t \cdot m_e^{2.66}) - 0.42 \quad (5)$$

where "ln" indicates that the natural logarithm is taken of the quantity within parentheses,

z = the number of standard deviations that a percent crop reduction is located away from 50 percent crop reduction; z is the Gaussian transform of percent crop reduction

t = exposure duration time in h

Substituting 525 h for t (a 75-day exposure[4] for 7 h/day, 0900–1600, always standard time),

$$z = 1.27 \ln m_e + 2.57 \quad (6)$$

Natural Background Effective Mean O_3 Concentration

A natural background effective mean O_3 concentration of 0.030 ppm (approximately equivalent to an m_a of 0.025 ppm) was assumed here for the 75-day, 7 h/day seasonal value.[4] The natural background is the concentration expected if man and his activities were removed from the nation. Soybean yield reduction was set to 0 percent at 0.030 ppm (Figure 1). Five of the 320 site-years of data had effective mean O_3 concentrations of less than 0.030 ppm. These sites are in Iowa, Michigan, Oregon (two sites), and Washington.

O_3 Concentration Statistics Studied

For each of the 320 site-years, 14 O_3 concentration statistics were calculated (Table I, column 1). These 14 statistics were selected based on earlier O_3 air quality data analyses[10] for rural and remote areas or because they had been used to determine effects on crops. These O_3 statistics were studied here for potential selection of a secondary NAAQS to limit crop reduction.

The two mean O_3 concentration statistics (m_e and m_a) were calculated if at least 50 percent of summer daytime hours had O_3 concentration data available for a site-year. Otherwise, that site-year was not used.

Averaging times of 1 and 8 h were used[10] for the other 12 statistics, the same averaging times used in the NAAQS for some other pollutants.[1] Although the crop reduction studies[6,7] used to develop crop reduction estimates (Equation 6) involved 7 h/day exposures (0900–1600, standard time), this did not preclude correlating estimated crop reduction with other averaging times such as 1 and 8 h. Three of the statistics used here considered all April 1–September 30 1-h O_3 concentrations. The other nine statistics dealt with 1- or 8-h daily maximum O_3 concentrations measured throughout an entire year (or entire O_3 sampling season). For each calendar day, 8-h running averages were calculated, starting with the first hour of a day (always using standard time) and ending with the last hour of that day. At least six hours of data were required to calculate each 8-h mean. To be valid, no more than two hours of data could be missing from an 8-h period. The highest of these running means for each day was selected as the daily maximum.

The second highest daily maxima in a year for 1 and 8 h were first determined. Maximum 1-month means of daily

maxima were calculated next. For ease in computing, the "months" used here were the first twelve 30-day periods in a calendar year. At least 20 daily maxima during a 30-day period were required to calculate a valid 1-month mean.

To determine maximum 3-month means of daily maxima, 3-month running averages were calculated, beginning with the first 30-day period in a year and ending with the last 30-day period. All three 1-month values were required to calculate one 3-month mean.

The last statistic studied here was the number of days/year that the 8-h daily maximum concentration exceeded three O_3 concentrations (0.06, 0.08, and 0.10 ppm).

Second Highest Daily Maximum Hour O_3 Concentration

Data on c_{2hih} are shown in Figure 2. This statistic approximates the present O_3 NAAQS. Values across the bottom line of numbers on Figure 2 indicate that 75 percent of the site-years achieved the present NAAQS of 0.120 ppm in years 1981–1985. Most (95 percent, left axis) of the site-years had yield reductions of 20 percent or less and half (51 percent) had yield reductions of 10 percent or less.

A maximum crop reduction line was plotted at the upper limit of crop reductions on Figure 2. Potential O_3 standards could be selected to achieve a maximum desired crop reduction. For instance, if no more than 15 percent crop reduction were desired at any agricultural NADB site, a c_{2hih} standard of 0.099 ppm could be specified (Figure 2 and Table I, column 4). After many years of vehicle emission control in the United States, only 40 percent (interpolated on bottom axis) of these site-years (Table I, column 8) achieved this 0.099 ppm potential standard in years 1981–1985. Thus, it might be difficult to achieve the additional emission reductions needed to limit soybean crop reduction to 15 percent by using this type of an ambient standard.

Figure 2 shows considerable scatter, indicating poor correlation between estimated crop reduction and this O_3 statistic, and leaving 42 percent of the variance unexplained (Table I, column 10).

Table I. Potential ambient O_3 standards that would limit soybean crop reduction to 5, 10, 15, or 20 percent.

O_3 statistic[a] (1)	Ambient O_3 standard that would limit soybean crop reduction to stated percent: 5% (2)	10% (3)	15% (4)	20% (5)	Percentage of agricultural NADB sites that achieved this potential standard in years 1981–1985: 5% (6)	10% (7)	15% (8)	20% (9)	Percentage of variance unexplained by regression of soybean crop reduction against this O_3 statistic (10)
1. Second highest daily maximum 1-h O_3 conc (ppm)	0.059	0.079	0.099	0.119	2	10	40	74	42
2. Summer daytime arithmetic mean O_3 conc (ppm)	0.035	0.045	0.055	0.065	10	39	73	93	4
3. Summer daytime effective mean O_3 conc (ppm)	0.042	0.052	0.063	0.073	14	45	77	94	1
4. 1-h O_3 conc (ppm) exceeded 5% of the time (Apr–Sep)	0.049	0.060	0.071	0.082	7	28	56	87	14
5. Maximum 1-month mean of daily maximum 1-h O_3 conc (ppm)	0.048	0.060	0.072	0.085	5	26	65	91	15
6. Maximum 1-month mean of daily maximum 8-h O_3 conc (ppm)	0.042	0.052	0.062	0.073	5	26	64	89	17
7. 1-h O_3 conc (ppm) exceeded 10% of the time (Apr–Sep)	0.041	0.050	0.060	0.070	6	20	48	86	18
8. Maximum 3-month mean of daily maximum 1-h O_3 conc (ppm)	0.042	0.053	0.065	0.076	5	23	60	89	21
9. Maximum 3-month mean of daily maximum 8-h O_3 conc (ppm)	0.034	0.044	0.054	0.064	3	15	48	85	24
10. No. of days/yr 8-h daily max O_3 conc exceeds 0.060 ppm	0	21	43	67	0	17	44	71	27
11. No. of days/yr 8-h daily max O_3 conc exceeds 0.080 ppm	—	—	6	25	—	—	17	61	27
12. 1-h O_3 conc (ppm) exceeded 20% of the time (Apr–Sep)	0.028	0.031	0.045	0.053	3	9	26	67	33
13. Second highest daily maximum 8-h O_3 conc (ppm)	0.058	0.073	0.089	0.105	3	14	46	82	36
14. No. of days/yr 8-h daily max O_3 conc exceeds 0.100 ppm	—	—	—	3	—	—	—	31	41

[a] Time definitions for the O_3 statistic: Daytime is 0900–1600, always standard time (7 h/day); Summer is Jun 1–Aug 31; If summer or specific months are not mentioned, then the entire year or entire O_3 sampling season is assumed.

Scatter Plots of Crop Yield Reduction versus Each of 14 O_3 Statistics

Each of the 14 O_3 statistics was correlated separately with estimated soybean crop reduction (Figure 1, calculated using m_e in Equation 6). The percentage of variance unexplained ($1 - R^2$) by each O_3 statistic was listed (Table I, column 10). Statistics 3–14 were listed in Table I in order from the lowest to the highest values in column 10. Bivariate frequency distribution scatter plots[4] were plotted for the number of site-years for estimated soybean yield reductions versus increasing O_3 concentrations for each of the 14 O_3 statistics.

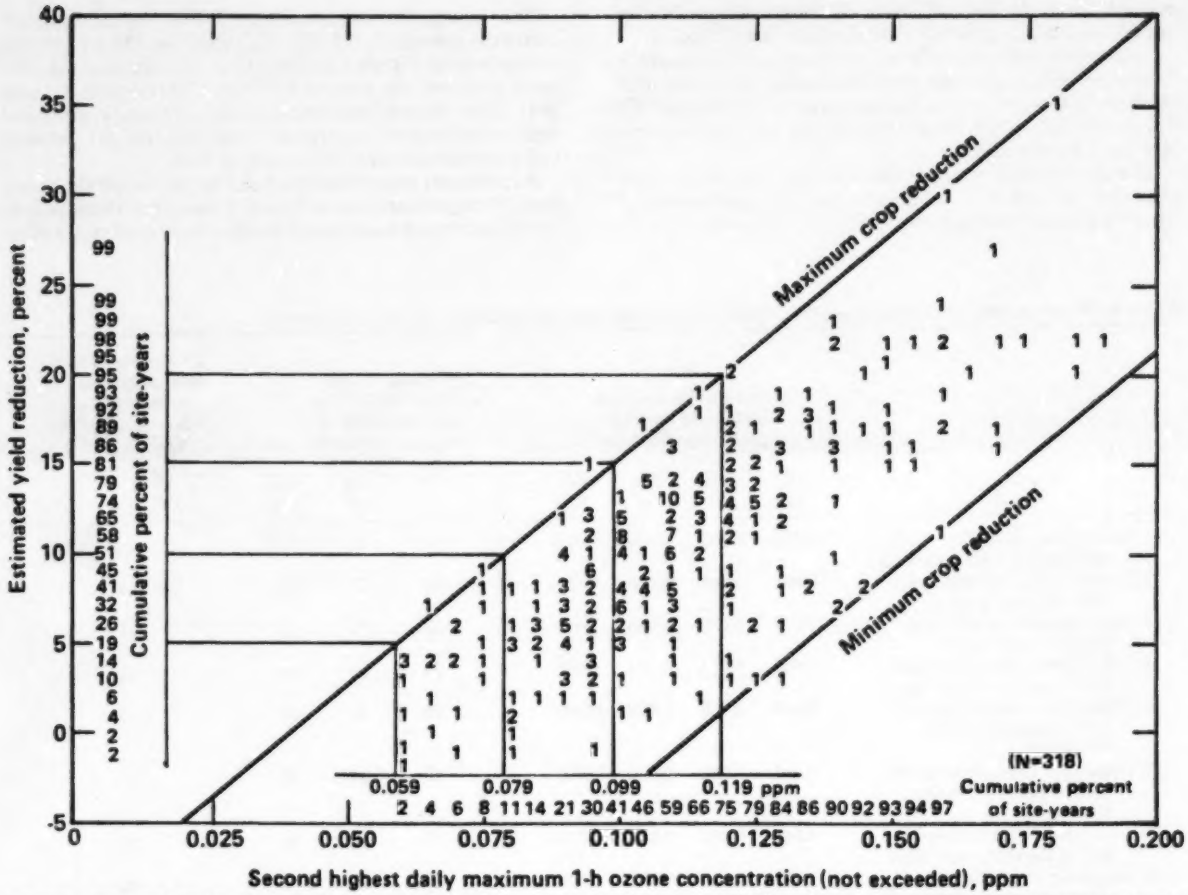

Figure 2. Number of site-years for estimated percent soybean yield reductions (for plants grown with adequate soil moisture during a 75-day exposure in summer) versus increasing second highest daily maximum 1-h O_3 concentrations measured at agricultural NADB sites during each year of years 1981–1985.

ble I, last column). The large scatter results in a minimum crop reduction line (plotted parallel to the maximum) with 19 percent less crop reduction than the maximum line. Some sites with 20 percent estimated crop reduction met the present O_3 NAAQS of 0.120 ppm. Other sites with only 3 percent estimated crop reduction (a crop reduction ratio of 20/3, or about 7/1) did not meet that standard and thus, based on this NAAQS statistic, might be required to adopt O_3 control strategies that are more stringent than necessary to limit crop reduction.

Effective and Arithmetic Mean O_3 Concentrations

Since the effective mean O_3 concentration was the statistic used in the crop reduction model (Equation 6), correlation of this statistic with estimated crop reduction gave an excellent fit, leaving only 1 percent of variance unexplained (Table I, line 3). This statistic did not explain all of the variance because crop reduction was rounded to the nearest 1 percent and the relationship between crop reduction and the effective mean was not perfectly linear (Figure 1) over the range of ambient effective mean O_3 concentrations measured (0.020–0.102 ppm).

The next best fit to the effective mean was the summer daytime arithmetic mean O_3 concentration, m_a (Figure 3), the statistic used in the original studies of the National Crop Loss Assessment Network (NCLAN).[6,7] The correlation for this statistic left only 4 percent of variance unexplained (Table I, line 2).

The Effective Ambient Standard Geometric Deviation

The effective ambient standard geometric deviation (s_{gae}) measures the degree of variation in ambient O_3 concentrations.[5] If all summer daytime hours at a site were at a constant O_3 concentration, s_{gae} would be 1. The greater the variation in hourly O_3 concentration values, the higher s_{gae} would be. The effective mean (m_e) can be expressed as a function of the arithmetic mean (m_a), v (−0.376), and the effective ambient standard geometric deviation (s_{gae}) of O_3 concentrations (Equation 19 in Reference 5):

$$m_e = m_a s_{gae}^{-0.5(1+1/v)\ln s_{gae}} \quad (7)$$

Equation 7 was rearranged to express and calculate s_{gae} for the 320 site-years of data:

$$s_{gae} = \exp\{([\ln(m_a/m_e)]/[0.5(1+1/v)])^{0.5}\} \quad (8)$$

where "exp" indicates that e (2.718) is raised to the power expressed within the braces.

The vertical scatter of estimated yield reduction (Figure 3) is a function of s_{gae} (Equation 7). For a given arithmetic mean, (Figure 3, horizontal axis) when the deviation in hour-

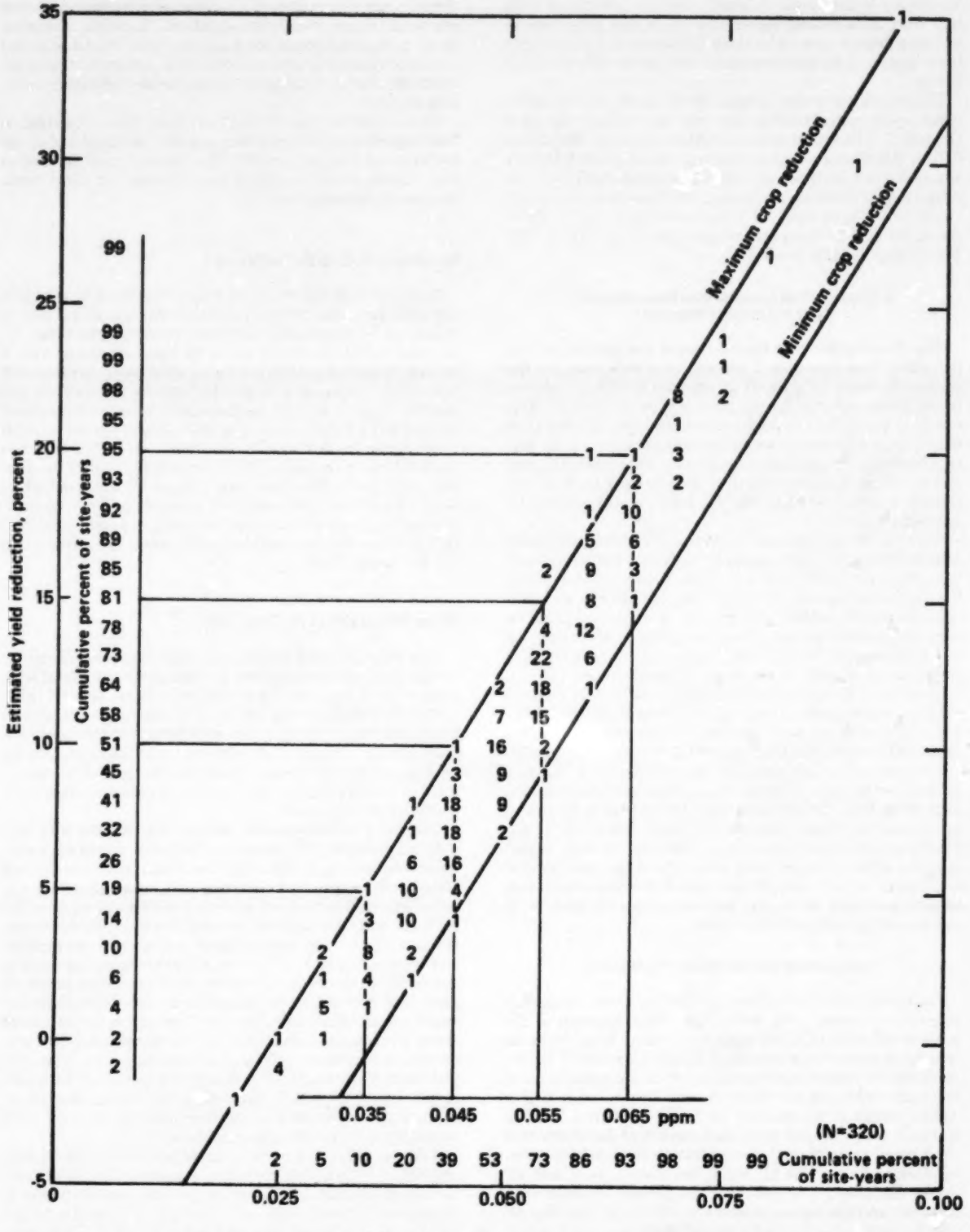

Figure 3. Number of site-years for estimated percent soybean yield reductions (for plants grown with adequate soil moisture during a 75-day exposure in summer) versus increasing summer (June 1–August 31) daytime (0900–1600, standard time) arithmetic means O_3 concentrations measured at agricultural NADB sites during each year of years 1981–1985.

ly O_3 concentrations at an ambient site was high, more crop reduction was expected (Equation 6,7) than when the deviation was low. This is because, for the same arithmetic mean, the higher hourly peak O_3 concentrations associated with high deviations caused higher effective means (Equation 2) and thus higher crop reductions (Equation 6) than did the lower hourly peak concentrations associated with low deviations.

This relationship can be seen, for instance, for the arithmetic mean concentration class not exceeding 0.055 ppm (Figure 3). The lowest crop reduction estimated (Equation 6,7) for this class, plotted at 9 percent, was at a North Dakota site with a low deviation of 1.20. The highest crop reduction estimated for this class, 16 percent, was from two sites, one of which is in Texas and had a high deviation of 1.71. Deviations for all 320 site-years ranged only from 1.15 to 1.83. The average deviation was 1.42.

A Comparison of an Arithmetic Mean Standard with the Present Standard

The distance between the maximum and minimum crop reduction lines was only 6 percent crop reduction for the arithmetic mean (Figure 3) as compared with 19 percent (three times as much) for the present type of standard (Figure 2). A potential arithmetic mean standard of 0.055 ppm would limit crop reduction on the maximum line to 15 percent at sites with the highest deviations in O_3 concentrations and to 9 percent at sites with the lowest deviations. This 15/9 ratio is much lower than the 7/1 ratio for the present O_3 NAAQS statistic.

Seventy three percent of the 1981–1985 site-years achieved this arithmetic mean of 0.055 ppm (Table I, column 8, and bottom line of Figure 3). Thus, it might be feasible to limit soybean crop reduction to 15 percent by using an arithmetic mean standard of 0.055 ppm. It probably would not be very easy to limit soybean crop reduction to 15 percent by using the present NAAQS statistic (c_{2hih}) set at 0.099 ppm since only 40 percent of site-years achieved this.

The reason the maximum and minimum lines in Figure 3 plotted close together is because the values of the arithmetic and effective means were similar. The numerical difference between them varied little as deviation varied (Equation 7).

The reason the maximum and minimum lines in Figure 2 plotted so far apart is because c_{2hih} is an extreme statistic, located far from the effective mean (which was used to estimate crop reduction, Equation 6). Small variations in s_{gae} produced large variations in c_{2hih}. Because of this "loose" coupling with estimated crop reduction, a c_{2hih} standard of 0.099 ppm, which only 40 percent of site-years achieved, would be needed to restrict soybean crop reduction to 15 percent at agricultural NADB sites.

Comparisons with the Present O_3 NAAQS

Columns 2–5 in Table I assume that only one standard is selected to control crop reduction. What happens if the present NAAQS of 0.120 ppm is retained in addition to specifying a new "crop reduction" limiting standard? Analysis of the 14 scatter plots resulting from the application of two such standards at a time showed that columns 2–5 in Table I remained the same for 12 of the 14 statistics. The two statistics that changed were the numbers of days/year that the 8-h daily maximum O_3 concentration exceeds 0.080 ppm, so columns 2–5 of line 11, which are now—, —, 6, and 25, would become—, 1, 6, and 11 if the present NAAQS were retained; and the same statistic for 0.100 ppm, and line 14, which is now —, —, —, and 3, would become —, —, 1, and 3. These results suggest that if any one of the other 12 potential standards were adopted, whether or not the present 0.120 ppm standard is retained would have no effect on reducing "maximum" crop reduction.

If a new arithmetic mean standard were adopted, also retaining the present NAAQS could have some advantages, though. After the present standard was exceeded (three times in any 3-year period),[2] additional exceedances at that site would clearly violate the standard. Therefore, whenever an air pollution forecast for a day suggested that additional 1-h O_3 concentrations were expected to exceed 0.12 ppm, air pollution control authorities could order temporary emission controls.

This is not the case for an arithmetic mean standard, a "retrospective" standard which can only be calculated at the end of an air pollution season. This statistic could be used to plan future overall emission controls but not short-term, temporary emission controls.

Sensitivity of Crop Reduction to v

As mentioned earlier, a v of -0.376 was used to calculate the effective mean ambient O_3 concentration (Equation 1) and a v of -1 was used to calculate the arithmetic mean. As was also noted above, the effective mean explained only 3 percent more variance in estimated crop reduction than did the arithmetic mean. This small difference is because of the narrow range (1.15–1.83) in the effective ambient standard geometric deviation, s_{gae}, measured at agricultural NADB sites. Thus, crop reduction estimates were not affected markedly if a v far from -0.376 (such as the v of -1 used for the arithmetic mean) was used (Figure 3). Crop reduction estimates were not very sensitive to variations in v, suggesting that ambient peak O_3 concentrations were not sufficiently high to markedly change crop reductions estimated using the arithmetic mean, m_a.

Water Stress Effect on Crop Yield

The soybean crop reduction equation used here (Equation 6) was obtained from studies of crops generally grown with adequate soil moisture. Crop yield was also measured (Table 4.1.1.8 in Reference 11) for both adequately-watered and water-stressed soybean plants exposed in outdoor open-top chambers to various O_3 concentrations. These studies by NCLAN participants were conducted because of the documented effects of soil moisture stress on plant response to O_3 and to other pollutants.

Generally, water-stressed plants were smaller and had reduced yields when compared with plants grown with adequate soil moisture. Although lower soil moisture did not always reduce the plant response to O_3, the interaction was found in a sufficient number of studies that scientists in the NCLAN program supported a modeling study to determine the impact of O_3 by soil moisture interactions on regional crop yield estimates. King[12] used yield forecasting models, developed to estimate the effects of soil moisture stress on yield, and a model he developed to predict O_3 by moisture stress interactions, to determine how much soil moisture stress protected soybean from O_3. The models predicted a 20 percent reduction in crop sensitivity to O_3 (e.g., a 10 percent yield reduction would be reduced to 8 percent). Although results vary with drought severity, crops, regions, and years, the possible effect of soil moisture deficits on crop yield responses to O_3 needs to be considered.

As noted above, the points plotted in Figures 2 and 3 were calculated with a crop reduction equation developed from studies of adequately-watered crops. Adding data points to these plots for water-stressed crops would lower the "minimum crop reduction" line on Figures 2 and 3. Thus, adequately-watered crops set the "maximum crop reduction" line where it presently is plotted and water-stressed crops, if plotted, would lower the present "minimum crop reduction" line.

Recent Data on Natural Background O_3 Concentrations

As noted earlier, estimated soybean crop reduction was set to 0 percent at an assumed natural background effective mean O_3 concentration of 0.030 ppm (Figure 1).[4] For an average site-year (s_{gse} = 1.42) an effective mean of 0.030 ppm is equivalent (Equation 7) to an arithmetic mean O_3 concentration of 0.027 ppm.

An average spring-summer natural background O_3 concentration in the range of 0.010–0.020 ppm was estimated recently.[13] If crop reduction is 0 percent when m_a is 0.027 ppm, then crop reduction would be −3 percent at 0.010 ppm and −2 percent at 0.020 ppm. If these more recent natural background O_3 estimates were used, only 2 to 3 percent crop reduction would need to be added to all the crop reduction estimates mentioned herein. Thus, crop reduction estimates would not be affected markedly by lowering the assumed natural background O_3 concentration.

Summary

A lognormal mathematical model was used to estimate soybean crop reduction as a function of ambient effective mean O_3 concentrations measured at each agricultural NADB site for each available year of data for years 1981–1985. These crop reduction estimates were correlated separately against each of 14 O_3 air quality statistics measured for each of the 320 site-years of data. The second highest daily maximum hour O_3 concentration (c_{2hih}), the present NAAQS statistic, correlated poorly, leaving 42 percent of variance unexplained, the worst correlation of the 14 statistics studied. The summer daytime arithmetic mean O_3 statistic correlated well with estimated crop reduction, leaving only 4 percent of variance unexplained, and might be a good statistic to consider for a future ambient air standard.

If the main purpose of the present O_3 NAAQS were to control crop reduction, then it has some limitations. The present standard limits estimated soybean crop reduction to 20 percent, but it also requires some sites with only 3 percent estimated crop reduction to reduce present O_3 concentrations that exceed that standard. The present O_3 NAAQS may be an efficient standard to prevent acute health effects but not to control chronic crop reduction.

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